

RHENIUM-CONTAINING PROTECTIVE LAYER FOR PROTECTING A COMPONENT  
AGAINST CORROSION AND OXIDATION AT HIGH TEMPERATURES

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Cross-Reference to Related Application:

This is a continuation-in-part of U.S. application No.  
10/279,580, filed October 24, 2002.

10 Background of the Invention:

Field of the Invention:

The invention relates to a rhenium-containing protective layer  
for protecting a component against corrosion and oxidation at  
high temperatures. The component, in particular a component  
15 of a gas turbine, is exposed to a flue gas or the like at a  
high temperature.

The invention relates in particular to a protective layer for  
a component that contains a nickel-base or cobalt-base  
20 superalloy.

Protective layers for metallic components that are intended to  
increase the resistance to corrosion and/or oxidation of the  
components are known from the prior art. Most of the  
25 protective layers are known under the collective name MCrAlY,  
where M represents at least one of the elements from the group

containing iron, cobalt and nickel, and further essential constituents are chromium, aluminum and yttrium. The latter may also be completely or partially replaced by an equivalent element from scandium or the rare earths.

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Typical coatings of this type are known from U.S. Patent Nos. 4,005,989 and 4,034,142. Moreover, it is known from the latter patent that an additional silicon fraction can further improve the properties of protective layers of the type

10 mentioned above.

Furthermore, Published, European Patent Application EP 0 194 392 A discloses numerous specific compositions for protective layers of the above type with the addition of further elements for various applications. The element rhenium added in amounts of up to 10% by weight is mentioned as well as many other elements that can be added if desired. However, on account of relatively unspecific, wide ranges for possible additions, none of the protective layers described is

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qualified for particular conditions, such as for example those that occur at rotor blades and guide vanes of gas turbines with high entry temperatures which have to be operated for prolonged periods.25  
Protective layers which contain rhenium are also known from U.S. Patent No. 5,154,885, Published, European Patent

Application EP 0 412 397 A (corresponding to U.S. Patent Nos. 5,273,712, 5,154,885, and 5,268,238), German Patent DE 694 01 260 T2 (corresponding to U.S. Patent No. 5,455,119) and International Patent Disclosure WO 91/02108 A1 (corresponding to U.S. 5,401,130). The disclosures that can be found in these documents as a whole are incorporated in its entirety in the present application.

Ways of applying a protective layer to a component which is to be subject to high thermal loads in a gas turbine are to be found in Published, European Patent Application EP 0 253 754 A1 (corresponding to U.S. Patent 4,743,462).

Efforts to increase the entry temperatures both in stationary gas turbines and in aircraft engines are of considerable importance in the specialist field of gas turbines, since the entry temperatures are important variables in determining the thermodynamic efficiencies which can be achieved by gas turbines. The use of specially developed alloys as base materials for components which are to be subject to high thermal loads, such as guide vanes and rotor blades, and in particular the use of single-crystal superalloys, makes it possible to have entry temperatures of well above 1000° C. By now, the prior art allows entry temperatures of 950° C and above in stationary gas turbines and 1100° C and above in gas turbines of aircraft engines.

Examples of the construction of a turbine blade or vane with a single-crystal substrate, which for its part may be of complex structure, are to be found in International Patent Disclosure WO 91/01433 A1 (corresponding to U.S. Patent No. 5,106,266).

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While the physical load-bearing capacity of the by now highly developed base materials for the highly loaded components are substantially problem-free with regard to possible further increases in the entry temperatures, to achieve a sufficient resistance to oxidation and corrosion it is necessary to have recourse to protective layers. In addition to the sufficient chemical resistance of a protective layer to the attacks which are to be expected from flue gases at temperatures of the order of magnitude of 1000° C, a protective layer must also have sufficiently good mechanical properties, not least with regard to the mechanical interaction between the protective layer and the base material. In particular, the protective layer must be sufficiently ductile to be able to follow any deformation of the base material without cracking, since this would create points of attack for oxidation and corrosion. In this context, the problem typically arises that an increase in the levels of elements such as aluminum and chromium, which are to be able to improve the resistance of a protective layer to oxidation and corrosion, leads to a deterioration in the ductility of the protective layer, so that there will be an expectation of mechanical failure, in particular of the

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formation of cracks, in the event of a mechanical load which customarily occurs in a gas turbine. Examples of the way in which the ductility of the protective layer is reduced by the elements chromium and aluminum are known from the prior art.

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International Patent Disclosure WO 01/09403 A1 discloses a superalloy for a substrate, which likewise contains rhenium. The document describes that the intermetallic phases formed by rhenium reduce the long-term stability of the superalloy. The  
10 problem can be alleviated by the addition of ruthenium.

Summary of the Invention:

It is accordingly an object of the invention to provide a rhenium-containing protective layer for protecting a component  
15 against corrosion and oxidation at high temperatures which overcome the above-mentioned disadvantages of the prior art devices of this general type, which has a good high-temperature resistance to corrosion and oxidation, a good long-term stability and, moreover, is particularly suitable  
20 for a mechanical load which is to be expected in particular in a gas turbine at a high temperature.

The invention is based on the discovery that the prior art protective layer has brittle chromium-rhenium precipitations  
25 in the layer and in the transition region between the protective layer and the base material. The brittle phases,

increasing amounts of which are formed with time and temperature in use, lead to pronounced longitudinal cracks in the layer and in the layer-base material interface during operation, ultimately leading to the layer becoming detached.

5 The interaction with carbon, which can diffuse out of the base material into the layer or diffuses into the layer through the surface during a heat treatment in the furnace, additionally increases the brittleness of the Cr-Re precipitations. The likelihood of cracks being formed is increased still further  
10 by oxidation of the chromium-rhenium phases.

To achieve the object, the invention describes a protective layer for protecting a component against corrosion and oxidation at a high temperature that is substantially composed  
15 of the following elements (contents given in percent by weight):

0.5 to 2% of rhenium;

20 15 to 21% of chromium;

9 to 11.5% of aluminum;

0.05 to 0.7% of yttrium and/or at least one equivalent metal  
25 from the group consisting of scandium and the rare earths;

a remainder being cobalt and/or nickel; and

production-related impurities.

- 5 In addition, the protective layer can include 0 to 1% by weight of ruthenium.

In accordance with a further object of the invention, the amount of cobalt is from 24 to 26 wt%. Preferably, the amount  
10 of cobalt is approximately 25 percent.

The advantageous effect of the element rhenium is exploited to prevent the formation of brittle phases.

- 15 It should be noted that the levels of the individual elements are particularly well matched with regard to their affects that originate from the element rhenium. If the levels of the elements are such that no chromium-rhenium precipitations are formed, there are advantageously no brittle phases formed  
20 during use of the protective layer, so that the service life is improved and lengthened. This is achieved not only by lowering the chromium content but also by taking account of the influence of aluminum on the phase formation by the reduction in the aluminum content.

The protective layer, with a good resistance to corrosion, also has a particularly good resistance to oxidation and is also distinguished by particularly good ductility properties, making it particularly well qualified for use in a gas turbine  
5 in the event of a further increase in the entry temperature. During operation, there is scarcely any embrittlement, since the layer has scarcely any chromium-rhenium precipitations that become brittle during use. The superalloy has no chromium-rhenium precipitations, or at most 6% by volume of  
10 chromium-rhenium precipitations.

It is advantageous for the rhenium content to be set at approximately 1.5% wt, the chromium content to be set at approximately 17% wt, the aluminum content to be set at  
15 approximately 10% wt, and the yttrium content to be set at approximately 0.3% wt. Certain fluctuations will occur as a result of large-scale industrial production.

The invention relates to a component, in particular a  
20 component of a gas turbine, which is to be protected against corrosion and oxidation at high temperatures by a protective layer of the type described above.

The protective layer described also acts as a bonding layer to  
25 a superalloy. Further layers, in particular ceramic thermal barrier coatings, can be applied to the layer.



In the component, the protective layer is advantageously applied to a substrate containing a nickel-base or cobalt-base superalloy. In particular, the following composition is  
5 suitable for the substrate (information in percent by weight):

0.03 to 0.5% of carbon;

18 to 19% of chromium;

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12 to 15% of cobalt;

3 to 6% of molybdenum;

15 1 to 1.5% of tungsten;

2 to 2.5% of aluminum;

3 to 5% of titanium; and

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optionally small amounts of tantalum, niobium, boron and/or zirconium, remainder nickel.

Such materials are known as forging alloys under the names  
25 Udimet 520 and Udimet 720.

Alternatively, the following composition may be suitable for the substrate of the component (details in percent by weight):

0.1 to 0.15% of carbon;

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18 to 22% of chromium;

18 to 19% of cobalt;

0 to 2% of tungsten;

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0 to 4% of molybdenum;

0 to 1.5% of tantalum;

15 0 to 1% of niobium;

1 to 3% of aluminum;

2 to 4% of titanium;

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0 to 0.75% of hafnium; and

optionally small amounts of boron and/or zirconium, remainder nickel.

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Compositions of this type are known as casting alloys under the names GTD222, IN939, IN6203 and Udimet 500.

A further alternative for the substrate of the component is  
5 the following composition (details in percent by weight):

0.07 to 0.1% of carbon;

12 to 16% of chromium;

10 8 to 10% of cobalt;

1.5 to 2% of molybdenum;

2.5 to 4% of tungsten;

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1.5 to 5% of tantalum;

0 to 1% of niobium;

20 3 to 4% of aluminum;

3.5 to 5% of titanium;

0 to 0.1% of zirconium;

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0 to 1% of hafnium; and

optionally a small amount of boron, remainder nickel.

Compositions of this type are known as casting alloys

5 PWA1483SX, IN738LC, GTD111, IN792CC and IN792DS; the material  
IN738LC is to be considered particularly preferred.

The following composition is considered a further alternative  
for the substrate of the component (details in percent by

10 weight):

approximately 0.25% of carbon;

24 to 30% of chromium;

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10 to 11% of nickel;

7 to 8% of tungsten;

20 0 to 4% of tantalum;

0 to 0.3% of aluminum;

0 to 0.3% of titanium;

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0 to 0.6% of zirconium; and

optionally a small amount of boron, remainder cobalt.

Such compositions are known as casting alloys under the names  
5 FSX414, X45, ECY768 and MAR-M-509.

The thickness of the protective layer on the component is  
preferably between approximately 100  $\mu\text{m}$  and 300  $\mu\text{m}$ .

10 The protective layer is particularly suitable for protecting a  
component against corrosion and oxidation while the component  
is being acted on with a flue gas at a material temperature of  
around 950° C, and in aircraft turbines even of around 1100°  
C.

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The protective layer according to the invention is therefore  
particularly qualified for protecting a component of a gas  
turbine, in particular a guide vane, rotor blade or other  
component that is acted on by hot gas upstream of or in the  
20 turbine of the gas turbine.